Auction Design, Incentives, and Buying Back Maryland and Virginia Crab Licenses

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Fisheries managers use buybacks to reduce fleet capacity, conserve fish stocks, and accomplish other goals. In 2009, Maryland and Virginia conducted auctions to buy back commercial fishing licenses. The auctions in both States had similar timing, objectives, and target populations. The divergent designs of the auctions, however, provide a case study with which to investigate effective buyback practices. We compare and contrast the market designs used by Maryland and Virginia, and describe how those differing designs influenced the respective outcomes.

Les gestionnaires des pêches recourent aux rachats de permis pour réduire la capacité des flottilles de pêche, protéger les stocks de poissons et réaliser divers objectifs. En 2009, les États du Maryland et de la Virginie ont organisé des ventes aux enchères pour racheter des permis de pêche commerciale. Le moment choisi, les objectifs et les populations cibles de ces deux États étaient similaires. Toutefois, les conceptions des enchères étaient différentes et offraient l'occasion d'examiner les pratiques de rachat efficaces. Nous faisons ressortir les similitudes et les différences des conceptions du marché utilisées par le Maryland et la Virginie, et nous décrivons de quelle façon ces conceptions ont influencé les résultats respectifs.

INTRODUCTION

Buybacks have become an important tool for fishery managers to address the detrimental effects of overcapacity—defined as having either an excessive number of fishing firms or overutilization of inputs. Buybacks in the United States, for example, have occurred in several fisheries including Washington State commercial salmon (Muse 1999), Bering Sea pollock (United States General Accounting Office 2000), Texas commercial bay and bait shrimp (Riechers et al 2007), and Northeast groundfish (e.g., Walden et al 2003). Squires' (2010) study contains a recent survey of buybacks. Despite the frequent use of buybacks, case studies report mixed results regarding their success (Holland et al 1999;

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United States General Accounting Office 2000; Curtis and Squires 2007; Thomas 2008). Some studies have questioned the ability of buybacks to produce welfare gains (Holland et al 1999; Weninger and McConnell 2000; Clark et al 2005, 2007). Critically, although buybacks are typically used to reduce the number of firms, their effectiveness is often thwarted by the failure to address input utilization at the intensive margin (Weninger and McConnell 2000; Clark et al 2005, 2007). Despite these drawbacks, buybacks continue to be an important tool for transitioning to rationalized fisheries and addressing distribution and conservation concerns (Squires 2010). The ultimate success of these programs hinges on the market design (Kirkley et al 2002; Larkin et al 2004; Curtis and Squires 2007; Squires 2010).

Our paper reviews best practices in buyback program design, and is intended for use by program managers to better achieve desired outcomes. To motivate an analysis of best practices, we rely on the recent simultaneous buyback of licenses in a single fishery by two different jurisdictions. In 2009, three auctions and two single-price, take-it-or-leave-it offers were conducted to purchase crabbers' rights to harvest Chesapeake Bay blue crab. Maryland, Virginia, and the Potomac River Fishing Commission (PRFC)[1] conducted the license buybacks following a National Marine Fisheries Service declaration that the crab fishery met the criterion for disaster assistance (Maryland Department of Natural Resources 2009a; Virginia Marine Resources Commission 2009a). We focus on the Maryland and Virginia fisheries and largely ignore the PRFC because it regulated only about 5% of the total Chesapeake landed weight from 1994 to 2009 (Virginia Marine Resources Commission 2009a).

Maryland conducted a discriminatory reverse auction; license holders competed to sell their license back to the state, and winning bidders received the amount of their bids as payment. However, participation rates did not meet the levels expected, so the state canceled the auction in favor of a posted price, take-it-or-leave-it offer.

Virginia conducted a somewhat more complex auction and honored the bids, although participation was still below expected levels. Neither mechanism performed particularly well from the management agencies' perspective. In Maryland, many crabbers who bid substantially above the posted price in the auction subsequently accepted the posted price offer, suggesting that the original bids greatly exceeded their reservation value. Conversely, some crabbers bid below the posted price offer but did not accept the offer. In Virginia, some crabbers sold their licenses in the auction and then purchased a new license on a secondary market, resulting in significant government outlays with little reduction in fishing effort. In this paper, we highlight market design decisions that diverged from best practices and led to the observed results.

AUCTION DESIGN AND THEORY

Transparency, or an understanding of the rules by all participants in advance of the auction, is fundamental to well-designed auctions. The rules should be simple, or at least no more complex than justified by the objectives of the auctioneer. The rules should

[1] The PRFC regulates commercial fishing in the Potomac from the Maryland/Washington, DC border to the mouth of the river at the Maryland/Virginia border (Point Lookout, Maryland and Smith Point, Virginia).

be neutral in that they do not offer an advantage to some bidders to the detriment of others.[2] If potential bidders do not understand how to win the auction, how their bid affects their likelihood of winning, or the conditions under which their bid would be rejected, they are less likely to participate or to submit a bid that reflects their true valuation. Anything that deters competition, including a violation of transparency, simplicity, and neutrality, would reduce the potential cost effectiveness of the auction (Krishna 2010).

Auction design starts with a definition of the good being purchased. This often-overlooked step forces the auctioneer to think carefully about the auction's objective and how their decision about what to purchase affects their objectives. For example, if the objective of the auction is to reduce the effort of small-scale crabbers, then licenses with small catch limits are probably a more appropriate good than licenses with large catch limits. The definition of the good to be purchased accounted for some of the difference in the auction outcomes of Maryland and Virginia. After defining the unit to be auctioned, the auctioneer has three key decisions to make which can be aided by auction theory: the format of the auction, the method of determining a winner(s) and clearing price(s), and how to set a reserve price.

Auction Format

The two primary reverse auction formats are static and dynamic.[3,4] The static auction tends to be lower-cost but the dynamic auction encourages participants to refine their estimate of the value of auctioned good as the auction progresses. A static reverse auction—commonly referred to as a sealed-bid auction—occurs in a single round. Each bidder submits their bids at the start of the auction and the auctioneer ranks them from lowest to highest and chooses the winner using a predefined clearing rule. The static design is simple and tends to be favored when values of the good are mostly driven by idiosyncratic differences between bidders—a situation referred to as *private values* in the auction literature. The static design is also favored when goods are identical and each supplier is selling a very small fraction of the total demand, or when there is a particular concern that bidder interaction would facilitate collusion (Krishna 2010).

A dynamic reverse auction occurs in multiple rounds and begins with a price sufficiently high that all sellers would presumably agree to sell. The price falls until supply from sellers equals the demand (or budget) of the auctioneer. A dynamic auction requires all participants to bid during each round and so may be considered slightly more complex than a static auction. The dynamic design tends to be favored when there is a large *common value* component of the good—that is, all participants would have the same or

[2] See Roth (2008) for a general discussion of the three characteristics of auction design.

[3] Forward auctions can be applied to fisheries as well (Garber and Bromley 2003); a forward auction circumvents the influx of effort that can result from expected subsidies (Clark et al 2005, 2007). There are some examples of this format's use in fisheries buybacks (Cerda-D'Amico and Urbina-Veliz 2000).

[4] Reverse auctions have been successfully used in many applications outside of fisheries, ranging from agricultural land conservation (Horowitz et al 2009) to Treasury securities (Hortacsu and McAdams 2010) and have been demonstrated to work in even the most complicated settings (Ausubel et al 2011).

similar value for the good—or when multiple items are being auctioned and their values have strong complementarities (Cramton et al 2006).

Clearing Rules

Every auction requires a decision rule for determining the winner(s) and the price to be paid to each winner (commonly referred to as the *clearing price*). In the simplest auction for a single license, a first-price sealed bid auction, the lowest bidder wins and receives a payment equal to their bid. Although simple and transparent, this clearing rule provides an incentive for participants to raise their bid above their fundamental value for the item, a practice known as *shading* (Krishna 2010).

In an auction for multiple-goods, the equivalent to the first-price auction is known as the pay-as-bid (or discriminatory) auction. Bids are ranked from lowest to highest and the lowest bids are accepted until the budget is exhausted (or the auctioneer's demand is satiated). Each accepted bid is paid the exact amount of the bid. Such a design also creates an incentive for participants to shade their bids up to the expected bid of the last accepted bidder. In an environment with a large budget and valuations that are highly heterogeneous—such as might be present in a fishery buyback auction—guessing the bid of the last accepted bidder can result in a wide diversity of bids with each bid offering very little information about the bidders' actual value for the license.

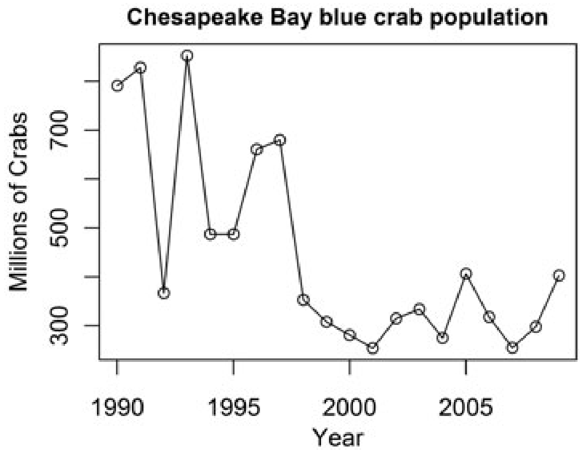
The tendency for participants to shade their bid can be reduced, if not eliminated, when the auction is designed so that a bid affects the likelihood of winning but not the price paid to the winner. The second-price auction is an example of such a pricing rule. When one unit is being purchased, the lowest bidder wins the right to sell their good to the state, but the price paid to the winner is equal to the second-lowest bid. With this design, no participant can benefit in expectation from bidding anything other than the lowest value at which they would sell the unit (Krishna 2010).

In a multiple-unit context, such as the crab license auctions, a clearing rule with similar properties to the second-price auction is a *uniform-price* auction, where each winning bidder is paid the bid of the lowest rejected bid.[5] Allocatively efficient pricing strategies, such as the uniform-price auction, are noted for eliciting bidders' values while guaranteeing that no single seller or group of sellers can claim after the auction that acceptance of their collective bids would have lowered the state's costs while achieving the same objective.

Reserve Price

Many auctioneers, especially in a public setting, impose a reserve price. In a reverse auction, the reserve price is the maximum amount that the auctioneer is willing to pay for the good being purchased. An explicit reserve price is a procurer's protection against paying unacceptably high unit prices for the purchased auction goods. In a license buyback program, the reserve price would limit the state's cost of purchasing any single license or a given number of licenses. However, if a publically announced reserve price is established at a level determined by potential bidders to be too low, it may reduce participation

[5] There are other, more complicated pricing strategies to solve the efficiency problems presented by the first-price design when there are multiple items to purchase, particularly when there are complementarities across items. See Cramton et al (2006) for details.



(Source: 2012 Blue Crab Winter Dredge Survey: http://dnr.maryland.gov/fisheries/crab/dredge.asp).

Figure 1. Total blue crab population, 1990–2009

(Reiley 2006; Hellerstein and Higgins 2010). In selecting a reserve price, the auctioneer is balancing their desire for a guarantee against exorbitant unit expenditures and the need for competition to generate low unit expenditures. Higher reserve prices encourage increased competition, but expose the auctioneer to higher unit costs.

MARYLAND AND VIRGINIA FISHERIES AND BUYBACK PROGRAMS

The blue crab fishery is the highest valued Chesapeake Bay fishery, with a 2010 dock-side value of $108.8 million (National Oceanic and Atmospheric Administration 2011). The fishery is managed independently, but in coordination, by Maryland, Virginia, and the PRFC. Maryland and Virginia manage their respective crab fisheries as limited access, with a system of transferable licenses that grant each holder the right to use up to a license-specific number of crab pots.

Although there have been recent signs of improvement, the crab population declined precipitously from the early 1990s to 2008 (see Figure 1), and harvest was approximately halved over the same period (Kaine 2008; O'Malley 2008). Management thresholds and target levels for stock abundance and fishing pressure were established for blue crab in 2003, in response to the recommendations of the Bi-State Blue Crab Advisory Committee (Chesapeake Bay Commission 2001). To meet the targets, Maryland and Virginia agreed to a 15% phased reduction (2001–03) of fishing effort compared with the levels of the late 1990s. Regulators implemented this reduction by closing fishing areas and shortening both work days and the length of the crabbing season. The states were concerned that if efforts to increase the blue crab stock were successful, an influx of latent fishing effort would limit the effectiveness of input controls.

Despite the effort reductions, population estimates in 2007 were so low that state fishery experts worried that a single significant storm could cause a fishery collapse (Kaine 2008). The low stock level and decline in harvest led Governors Martin O'Malley

(Maryland) and Tim Kaine (Virginia) to appeal to the Department of Commerce for a declaration of a Fishery Resource Disaster in May 2008. Under the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 (United States Congress 2007), such a declaration would make funds available to the states which could be used to restore the fishery and to provide economic relief to affected crabbers. Secretary Gutierrez declared the Chesapeake Blue Crab fishery a disaster on September 22, 2008. Maryland and Virginia developed plans for how funding would be used and submitted proposals in January 2009. Both states were awarded approximately $15 million to implement their plans for a mix of habitat enhancement, research, employment programs for watermen, and license buybacks.

The submitted buyback plans were preliminary. The Maryland plan mentioned a reverse auction as a "strategy being considered," while the Virginia plan discussed a bidding or negotiation process of some kind. However, the plans did include descriptions of Maryland and Virginia's goals for and expected benefits of repurchasing licenses. We drew on these documents, as well as personal consultation with management officials, to characterize the goals of the buyback from the states' perspective.

Maryland

Maryland has four commercial license categories: the Limited Crab Catcher (LCC) license category, which allows use of up to 50 crab pots, and three categories of Crab Harvester (CH) license (300, 600, or 900 pots). There are far fewer CH licenses than LCC licenses. Maryland focused on the LCC license and did not include the CH licenses in the buyback. The LCC is a single undifferentiated category of license, and all 3,676 license holders were eligible for the buyback. Maryland's inferred objective function was extremely simple: to remove the largest number of crabbers possible from the fishery. In support of this, the auction good was defined as a license; incoming bids would be ranked from lowest to highest and bought sequentially until the budget was expended. A strategy targeting the CH licenses would have likely removed more active effort from the fishery.

Although the auction was open to all license holders, Maryland looked to induce participation especially from individuals not currently engaged in the fishery—that is, from latent license holders. Because licensed watermen have many motivations for holding and valuing licenses, Maryland was uncertain under what conditions latent effort would re-enter the fishery.[6] Although the Chesapeake Bay Commission (2001) had previously recommended that latent effort be reduced, the Commission did not suggest a mechanism to accomplish the task. By targeting latent licenses in the buyback, Maryland sought to remove some of this uncertainty from the fishery.

Because the definition of the auctioned good used by Maryland did not explicitly select for latent effort, the auction was augmented with an additional rule. Individuals

[6] Profit did not seem to be a primary motivator for many watermen, especially holders of latent licenses. Calculations indicate that roughly half of all license holders fail to generate positive profits (DePiper and Lipton 2009), even in years of high crab populations. Open house meetings prior to the auction suggested that the economic incentives underlying the value of the licenses was extremely heterogeneous and included bequest motives, joy of crabbing, identity value, option value, and family history, among others (Maryland Department of Natural Resources 2009b). Econometric analysis indicates that these alternative values underlie a significant portion of the licenses' value for some individuals (DePiper 2012).

with no recorded crab catch between April 1, 2004 and December 15, 2008 were told that if their bid was not accepted, or if they did not participate in the buyback, their licenses would be subject to new restrictions for the 2010 season. The proposed regulations would severely reduce the usability and transferability of their licenses, and were aimed at inducing individuals not currently engaged in the fishery to participate in the auction. A total of 1,046 individuals were classified as latent prior to the buyback. Crabbers may not have considered these restrictions seriously, because roughly six months prior to the auction very similar restrictions were retracted in the face of strong political opposition (Maryland Department of Natural Resources 2009c).

In a letter sent to all LCC license holders Maryland announced the details of the competitive buyback (Maryland Department of Natural Resources 2009d). Maryland license holders were told that an independent economic analysis had estimated a fair market value for LCC licenses and any bids exceeding that (unspecified) amount would be rejected,[7] that the range of bids received would be used to determine a maximum price to be paid in the auction, that winning bidders would be paid the amount of their bid, and that Maryland had a goal to buy 2,000 licenses. The $2.5 million buyback budget was unspecified in the letter (though the total funds available under the disaster assistance would have been known to the public).

Bidders were also told that their bid should not include the value of associated business capital. Buybacks have often been designed to directly remove capital (vessels and fishing gear) from fisheries (e.g., Schelle and Muse 1984; Curtis and Squires 2007). Buybacks targeting both licenses and fishing capital can address the fact that fishing gear can be imperfectly malleable capital, meaning that the capital's value is inextricably linked to the license or permit (Clark et al 1979). However, targeting capital can be much more expensive. In the blue crab fisheries, fixed costs represent roughly 23% of total crabbing costs (Lipton et al 2001), and thus are sufficiently low that excluding capital from the buyback design likely did not affect outcomes of the buyback.

Participation in the auction was much less than Maryland had anticipated. Disappointed with the results, Maryland rejected all auction bids, switched to a fixed-price buyback mechanism, and increased the buyback budget to $3 million. A single price of $2,260 was offered in exchange for a LCC license for any interested participants. A more thorough explanation of Maryland's dissatisfaction with the auction format, along with the selection of the fixed-price offer, is presented in the Results section.

Virginia

Table 1 provides a comparison of the most salient components of Maryland and Virginia's buyback auctions. Two general categories of licenses exist in Virginia; peeler pot and hard pot, and 684 individuals (37%) held both categories of licenses at the time of the buyback. Hard shell crabs are harvested by using food bait (often eel, bull lip, or chicken and turkey necks). Peeler crabs are caught and held until they complete their molt, at which time

[7] The economic analysis undertaken prior to the buyback was intended to highlight the potential drawbacks of a posted offer compared with an auction format specifically because of the lack of information regarding the license value (DePiper and Lipton 2009). This statement from Maryland was intended to encourage competitive bidding, and represented gamesmanship more than the existence of actionable information.

Table 1. Comparison of auction rules across Maryland and Virginia

	Maryland		Virginia		
License classifications	Latent	Active	Full-time	Part-time	Wait-listed
Separate auction by classification	No		Yes		
Budget subdivision (%)	None		50	30	20
License size (pots)	50		85, 127, 170, 210, 255, 425		
Auctioned unit	50 pot license		License per pot per day		
Winner determination	Ascending bid		Ascending bid per pot per day		
Total budget ($)	3,000,000		6,725,161		
Usage restrictions	None[a]		Wait-listed		

Note: [a]Maryland's latent licenses became restricted between the auction and fixed-price offer.

they are sold as soft shell crabs. Since molting crabs do not feed, peeler pots employ live male crabs as bait. Females mate directly after molting, and thus a fertile male crab serves as good bait for female "peeler" or molting crabs. Soft shelled crabs receive a significant price premium compared with hard crabs. Within these general categories, multiple license sizes exist, from 85 to 425 pots per day. For the purposes of the buyback, license holders were placed into one of three different categories that depended on their 2004–07 harvest. Full-time crabbers were defined as having reported an average of at least 100 days of harvest for those in the hard shell fishery and at least 60 days for those in the peeler fishery. Part-time crabbers were those who reported less than these limits, but had some positive catch history. Crabbers were wait-listed in either the peeler or hard shell fishery if they reported no harvest days for that respective fishery between 2004 and 2007. Wait-listed licenses were deemed frozen, and not allowed to be used for crabbing, transferred, or sold until the estimated crab population older than one year exceeded 200 million for three consecutive years. Prior to the buyback, the crab population had not consistently surpassed the 200 million threshold since the early 1990s, although it was surpassed annually in 2009–11.

Virginia announced the buyback in a letter sent to all eligible license holders (Virginia Marine Resources Commission 2009b). License holders were told that the budget for the buyback program was $6,724,470. The state would spend 50%, 30%, and 20% of the available budget to buy licenses from full-time, part-time, and wait-listed fisherman, respectively. Each bid would be divided by the product of the maximum number of pots allowed by the specific license and the average number of actual reported days of harvest for each crabber in 2004–07, to calculate a bid per pot-day (the auctioned good). Although not explicitly indicated in the auction instructions, the bids of wait-listed individuals, who had no harvest history between 2004 and 2007, were ranked in ascending order by dividing the bid by the total number of pots allowed by the license being bid upon.[8] Normalized bids would be compared with bids from the same license category and bought sequentially, from lowest to highest bid per pot-day, until

[8] For individuals who received the license for the first time in 2008 or 2009, that year's crabbing effort was used to calculate the bid per pot per day value.

all funds in the category were expended (license holders were told their exact classification). Winning bidders would be paid the amount of their bid and were told that they would be eligible to re-enter the fishery by purchasing a license from another fisherman. Finally, Virginia reserved the right to reject any bids that it considered to be "excessive."

Virginia effectively ran three separate auctions, with the objective of minimizing the dollars spent per pot-day while exhausting their budget (or exhausting the total bids below their confidential reserve price). Such a strategy purchases licenses from crabbers who place the lowest value on a day of crabbing, which does not necessarily prioritize either latent effort or active effort.

Removing the historical days crabbed from the normalization rule would remove many more licensed pots from the fishery. Conversely, if the removal of active effort is the overriding objective, a more formal efficiency measure could have been used to rank licenses in these auctions. Walden et al (2003) developed a data envelopment analysis of the New England groundfish fishery, which was used to rank vessels and permits for buyback. The simulations in Walden et al (2003) suggest that these efficiency rankings are much more effective at removing active effort from the fishery compared with the less sophisticated rankings used by Virginia. The trade-off is that the high technical expertise needed to accurately develop and run efficiency analysis can be prohibitive, particularly with the exogenous time constraints often imposed on opportunistic buybacks. Virginia's normalization rule amounted to a "middle ground" approach, directly supporting the targeted removal of neither latent nor active effort and consequently undermining the effectiveness of the buyback.

The potential for an undesirable outcome caused by Virginia's lack of clear prioritization of buyback objectives was further compounded by dedicating 50% of the available funds to buying licenses from full-time crabbers. These 304 individuals are most engaged in the fishery, most likely to talk to other commercial crabbers, and otherwise have strong ties in the crabbing community. As a result, they might be best able to collude or otherwise manipulate the auction outcome, violating the neutrality tenant of auctions. While there is no evidence of overt market manipulation, it cannot be ruled out given the relatively small number of full-time bidders. Virginia could have almost certainly benefited from pooling the part-time and full-time crabbers into a single auction to foster greater levels of competition. This highlights the problems associated with segmenting a buyback into groups too small to sustain the competitive behavior that auctions are designed to leverage.

THE AUCTION RESULTS

Maryland

Bids for latent license holders (mean \$7,667; median \$3,675; max \$150,000; min \$30; standard deviation \$16,761) were significantly lower than active license holders (mean \$16,749; median \$5,000; max \$300,000; min \$250; standard deviation \$40,077), as determined by a Wilcoxon rank-sum test (p-value < 0.001). A two-tailed binomial test for the equality of participation rates also indicates significant differences (p-value < 0.001) with 8% participation for active license holders and 27% for latent ones. These participation rates suggest that the auction design failed to provide the population of potential bidders

Table 2. Maryland LCC single price buyback results

Status	Accepted	% Accepted	% Bidding	Mean bid	Median bid	Bid standard deviation
				($000)	($000)	($000)
Active	249	9.51	40.56	4.93	3.50	6.80
Latent	434	41.02	48.39	4.60	2.73	9.10

with confidence in the buyback. The variation in bid values even among latent crabbers suggests that the auction did not attract crabbers with the lowest-valued licenses and did not foster effective competition.

The 493 bids in the auction fell far short of the 2,000 licenses that the state targeted to purchase. Further, an overall mean bid of $11,540 was much higher than Maryland expected, given both secondary market prices and a net present value analysis conducted prior to the buyback suggested the average value of the license would likely be less than $3,000 (DePiper and Lipton 2009).

In switching to the fixed-price offer, the $2,260 offer was selected after reviewing the actual bids received within the auction. The $2,260 price was the mean bid of the bottom 50% of the bid distribution. Maryland used two arguments to justify concentrating their analysis on the bottom 50% of the bid distribution. First, there was a clear discontinuity in the bid distribution at $5,000 (the median bid value was $4,900). Second, a search of classified ads and other posted prices for LCC licenses in the secondary market provided no evidence that an LCC license separate from other fishing assets was worth more than $5,000. Maryland concluded that the $4,900 cutoff provided a useful upper limit on what would be classified as a "reasonable" bid. The $2,260 price was chosen given its consistency with anecdotal evidence on market clearing prices, its status as the mean of the "reasonable" bid distribution, and the belief that it would keep the buyback within budget.

Table 2 provides summary statistics for the posted price component of the Maryland buyback. The results again are grouped by active and latent crabber designations, although no priority was given to those classifications within the actual buyback. The posted price garnered much higher participation than the auction, driven primarily by increased participation by latent crabbers.

Of the 282 latent crabbers who previously bid in the auction, 210 (~74%) accepted the posted price. In addition, 372 individuals who accepted the posted price had not bid in the previous auction. Restrictions on latent crabbers were implemented between the auction and posted price buybacks, resolving a major source of uncertainty. As a result, a clean comparison between the two markets is not possible for latent crabbers. Participation by individuals classified as active was not subject to the additional restrictions. Only 101 active individuals (41%) accepting the posted price had previously submitted a bid in the auction.

Figure 2 depicts the cumulative distribution of bids in the Maryland auction, grouped by acceptance or rejection of the posted price offer. Eleven individuals rejecting the posted price (6%) had previously bid below $2,260. Roughly 33% of individuals, or a total of 103 license holders, who accepted the price of $2,260 previously had bid more than double

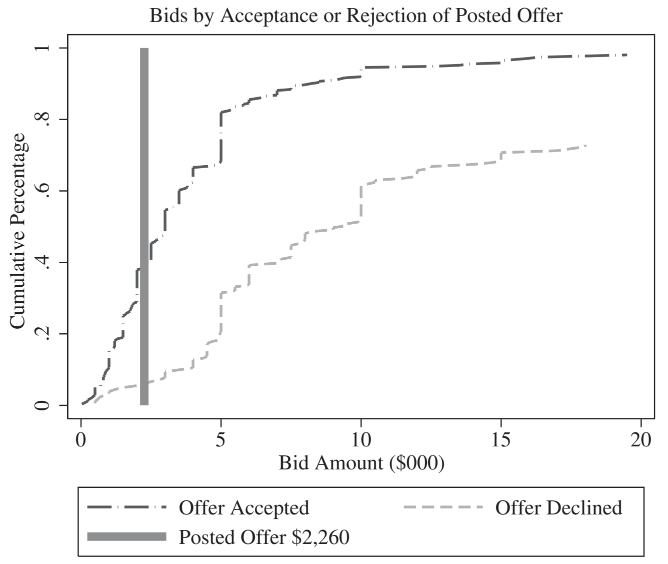


Figure 2. Maryland bids grouped by posted price participation

Table 3. Virginia commercial pot license auction bids ($ thousands)

Status	Obs	Mean	Med	SD	Min	Max	Bid
Hard pot		($000)	($000)	($000)	($000)	($000)	(%)
Full-time	49	114.41	98.00	116.83	6.00	600.00	25.26
Part-time	232	59.10	30.00	73.30	0.50	634.00	24.29
Wait-listed	141	20.33	10.00	29.44	1.00	220.00	43.65
Peeler pot							
Full-time	27	40.36	20.00	58.53	2.00	200.00	24.11
Part-time	126	38.48	15.25	50.99	0.50	300.00	29.44
Wait-listed	89	19.01	8.00	23.20	1.00	125.00	59.73

that value in the auction, suggesting significant bid shading. These seeming preference reversals are likely a result of weak signals regarding the licenses' value.

Virginia

Table 3 summarizes the bids in Virginia's license buyback. Unlike Maryland's handling of latent licenses, the Virginia program put up-front limitations on the future use of wait-listed licenses. Given their restricted usage, the distribution of bids for wait-listed crabbers is wider than expected. A Kruskal–Wallis test suggests that the bids for the full-time, part-time, and wait-listed license holders are drawn from population distributions with significantly different valuations (p-value = 0.0001). Participation rates were 23% for license holders in the full-time and part-time classifications, and 34% for wait-listed individuals. A Pearson chi-square test for independence was rejected (p-value = 0.000), indicating that the participation rate for wait-listed individuals differed significantly from

Table 4. Overview of accepted bids in the Virginia crab pot license buyback

Status	Number	Mean	Standard deviation	Median	Minimum	Maximum	% Accepted
Hard pot		($000)	($000)	($000)	($000)	($000)	
Full-time	33	57.67	38.93	50.00	6.00	150.00	67.35
Part-time	73	18.55	19.67	10.00	0.50	100.00	31.47
Wait-listed	103	8.72	7.52	6.00	1.00	35.00	73.05
Peeler pot							
Full-time	26	54.52	43.26	39.50	5.00	175.00	96.30
Part-time	58	11.75	9.62	9.50	0.50	50.00	46.03
Wait-listed	66	7.13	5.14	5.38	0.50	21.00	74.16

Table 5. Bids of individuals that re-entered the fishery after selling license to Virginia

Status	Reentered sellers	Mean	Standard deviation	Minimum	Maximum	Expenditure	Pots removed
Hard pot	(#)	($000)	($000)	($000)	($000)	($000)	(#)
Full-time	5	99.00	32.09	65.00	150.00	495.00	620
Part-time	7	43.76	27.96	24.00	100.00	276.32	510
Wait-listed	0	N.A.	N.A.	N.A.	N.A.	N.A.	0
Peeler pot							
Full-time	8	85.50	49.73	25.00	175.00	684.00	0
Part-time	7	25.57	12.27	9.00	50.00	154.00	0
Wait-listed	1	5.00	N.A.	5.00	5.00	5.00	0
Total	28	59.62	44.07	5.00	175.00	1,669.32	1,130

the participation rates of full-time and part-time individuals. Virginia compared the bid distribution with average gross revenues over 2004–07 to better understand the auction outcomes and identify "excessive" bids.

Table 4 provides an overview of the accepted bids within the Virginia auctions. Ultimately, Virginia spent $6,725,161—slightly more than their budget—buying back 359 licenses. Because the Virginia license buyback dedicated 50% of their budget to buy the most active licenses, a high percentage of the bids submitted by full-time crabbers were accepted.

With a secondary market for crab licenses, some crabbers who sold a license to Virginia re-entered the fishery by purchasing a license from an eligible license holder.[9] Table 5 provides summary statistics for the bids associated with individuals who re-entered the blue crab fishery after selling their license to Virginia through the buyback. For each individual who re-entered the fishery an estimate of the number of active pots retired through the buyback can be calculated by differencing the maximum number of pots allowed by licenses that they sold to Virginia and those they subsequently purchased to re-enter the fishery. This calculation represents an upper bound on the number of

[9] Licenses could only be bought from individuals classified as full-time or part-time who did not sell to Virginia in the buyback.

active pots removed if the seller of the repurchased license was using their license very little. Conversely, the calculation represents a lower bound for the number of active pots removed from the fishery when a second license was purchased from a fisherman who was using all of his allotted pots. The effort (and thus number of active pots) associated with the repurchase transaction is not known, and thus a more accurate representation cannot be estimated. Nevertheless, this calculation provides a sense to the problem re-entry caused in Virginia's ability to reduce active effort through the buyback. The fact that fishermen sold licenses through the buyback and then repurchased licenses on the secondary market suggests that these fishermen profited from the buyback—had Virginia purchased directly from the eventual sellers, cutting out the middleman, whatever reduction in active effort was achieved would have been achieved at lower cost.

The result of this simple difference calculation described above is represented in the final column of Table 5, and indicates that Virginia spent a total of \$1,669,315 ($\sim$ 25% of the buyback budget) to achieve a net reduction of 1,130 licensed pots. This net reduction came at a relatively high average price of \$1,477 per pot. Additionally, some of these individuals bought a second license with the proceeds of the buyback. A total of four individuals who sold a single license in the buyback bought two licenses upon re-entering the fishery. Given that roughly a quarter of the total budget was expended buying the licenses of individuals who subsequently re-entered the fishery, these results suggest that re-entry severely impacted the buyback's ability to reduce active effort.

LESSONS FROM MARKET DESIGN

The results suggest that the Maryland and Virginia auctions were not particularly successful. The Maryland auction was cancelled subsequent to receiving the bids. And while some licenses were purchased in the Virginia auction, the re-entry of crabbers receiving some of the highest payouts suggests that an alternative design would have decreased potential effort much more effectively. The three characteristics of auction rules—transparency, neutrality, and simplicity—provide insight into why the two auctions failed to achieve their stated objectives.

Maryland and Virginia failed to provide transparent information regarding the objectives and rules of the auction. Maryland's instructions did not state the budget for the buyback, which is a critical piece of information for someone trying to calculate a bid in a discriminatory auction. Virginia failed to detail exactly how wait-listed licenses would be ranked.

Neither state defined the excessive bid level that would automatically disqualify bidders from buyback consideration, or what metrics would be used to define an excessive bid. Both states had good reason to set a reserve price, and perhaps even to keep the reserve price confidential.[10] But auction results likely would have been improved by

[10] The evidence on setting a confidential reserve price is mixed. Confidential reserve prices are theoretically effective in the purchase of items with a common value component (Vincent 1995). Some empirical evidence suggests that confidential reserve prices deter participation in the market (Katkar and Reiley 2006), while other empirical evidence suggests essentially no difference in auction outcomes between a confidential and an announced reserve price (Bajari and Hortacsu 2003). Combining confidential reserve prices with a dynamic auction may be beneficial, as the secret reserve price would resolve focal-point issues, and dynamic auctions encourage price discovery

clearly communicating their decisions to potential participants, and not suggesting that the reserve price might be arbitrary.

When a hidden reserve price is combined with the pay-as-bid design described above, the optimal participant strategy is to bid as high as they believe the respective state would pay for a license. Crabbers would expect a higher clearing price if they had information to suggest that participation would be low, conditional on the reserve price being at least as high as the clearing price. In other words, the selected design encouraged crabbers to submit large bids if they believed few bidders would participate, but the state would spend the allocated budget as promised.

The danger of announcing a public reserve price is that it can serve as a focal point—bidders who would have otherwise bid less might instead bid the reserve price. Ultimately the large diversity of bids in Maryland and Virginia, and the seeming preference reversals between Maryland's two market designs, suggests that a publicized reserve price policy could have been beneficial. Given the thin market for licenses, this common information would have been useful for individuals formulating a bidding strategy. In hindsight, the danger of the public reserve price serving as a focal point for bids was moot for Maryland, as they ultimately switched to a fixed-price offer, and could have done no worse by publically announcing a reserve price in the auction.

Both Maryland and Virginia opted to use a sealed-bid mechanism. Given the potential for collusion among participants, the relative inexperience of most crabbers with auctions, and the costs associated with assembling a large number of potential sellers in a single place, the static sealed bid auction is almost certainly preferable to the dynamic auction format for these fisheries. However, both states could have benefited from open house forums to answer questions specifically on the auctions. A sealed-bid auction gives each bidder one opportunity to interact with the auctioneer. There is no built-in scope for learning. Mock auctions could have provided additional familiarity with the auction design prior to the actual auctions. Experimental economics has long implemented practice rounds to familiarize subjects with the design of the experiment prior to "live" rounds (Cummings et al 2004; Schilizzi and Latacz-Lohmann 2007), and this approach has previously been suggested for use in fishery buybacks (Groves and Squires 2007). The New England groundfish buyback included a pilot round of the buyback, used to fine-tune the market design, in addition to familiarizing potential participants with the market, prior to full implementation (Kitts et al 2000). Both practice rounds and a formal pilot would have served to increase the common information held by participants, an especially important consideration in a one-shot setting.

Instead of an allocatively efficient design, both Maryland and Virginia opted for a pay-as-bid auction where each winner received an amount equal to their bid. This likely relates to the fact that second price auctions, and its multi-unit extensions, are used less frequently (Rothkopf et al 1990), and thus managers are less likely to be familiar with its theoretical benefits and participants are less likely to be familiar with its structure.

Nevertheless, such a strategy had important consequences. With an identical number of participating bidders, procurement costs using a pay-as-bid auction are expected to be lower than a uniform price auction because low bidders are paid less than they would

(Cramton 2009), an important consideration when bidder information is low and there are real concerns about fairness.

have received under a uniform pricing rule.[11] Participation is not, however, expected to be identical using pay-as-bid and uniform pricing rules. Bidders who are concerned about "leaving money on the table" might decline to participate in a pay-as-bid auction. That is, individuals are unlikely to bid if they might regret participating in the auction after receiving a price significantly less than their fellow crabbers. Paying a uniform price alleviates that "*winner's curse*" and encourages participation. Taking issues of participation into account, applied experience suggests that the pay-as-bid approach would likely increase the overall cost of the program, compared with a uniform price auction (Kahn et al 2001).

Virginia's decision rule relied on the average number of days crabbed between 2004 and 2007. This information was not readily available to crabbers beyond their own accounting, which might differ from the official data. The decision rule could have given an undue advantage to licensees who kept detailed, accurate harvest records over long periods of time that were consistent with the records they reported to the State. Virginia could have easily alleviated this participation cost by providing all potential bidders with the days of harvest that would be used to calculate their bid ranking. The distribution of days of harvest for each auction segment also could have been publicized so that bidders could compare their days of harvest to the ranking distribution.

Effective auction design relies on the characteristics of transparency, neutrality, and simplicity. Auction performance also crucially depends on utility maximizing economic agents who can accurately value the good being auctioned and cannot collude (Vickrey 1961). Both Maryland and Virginia failed to fully integrate these critical issues into their market design, primarily for very different reasons. In Maryland, the value uncertainty associated with proposed regulations for latent permits greatly influenced individuals' participation decisions, underscoring issues with market transparency. This is evident from the higher participation rate after the uncertainty had been resolved, and with strong signals from the state as to the fair market value of the license, in the simpler fixed price buyback. In Virginia, the ranking of bids using unpublicized catch histories could have violated the objective of neutrality by providing undue advantage to individuals who knew their official records. The fact that a quarter of the total available funds were expended buying licenses from individuals who subsequently re-entered the fishery highlights this issue. Both states would have benefited from stronger lines of communication to the potential participants including practice or question and answer sessions to familiarize participants with the buyback design, public reserve prices as value signals, and clearly defined auction objectives.

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[11] Note that over time in dynamic pay-as-bid auction, bidders learn the approximate clearing price, and learn not to bid low, eroding the potential cost advantage.

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